07-044 Radiation Physics Modeling

QUARTERLY TECHNICAL PROGRESS REVIEW

TITLE:	**Physics Based Modeling - Radiation**
QUARTER:	**4Q FY07**
COORDINATING CENTER:	**GSFC**
PARTICIPATING CENTERS:	**None**
OTHER PARTICIPANTS:	**Vanderbilt University, University of Florida, EMPC, SLAC, GEANT4 Space User's Group, LANL, CERN, ESA, CNES, QinetiQ**
PROGRAM AREA:	**NEPP**
TASK MANAGER:	**Michael Xapsos/GSFC**
FY07 FUNDING:	
CUSTOMER:	**OSMA/Brian Hughitt**

TASK DESCRIPTION

Physics Based Modeling - Radiation

- Recent research on emerging technology has uncovered shortfalls in the techniques used to predict component performance, i.e. the data cannot be collected in a way that it can be used as input to any existing model. A promising approach to improving the prediction techniques involves the development and application of software packages to simulate radiation effects. The specific and immediate need is to develop Single Event Effects (SEE) and displacement damage techniques.

- FY07 focuses on model development. The overall effort is called RADSAFE and looks to tie in full circuit and system effects into a cognizant solution.

GOALS/OBJECTIVES

Physics Based Modeling - Radiation

- Develop research tools to improve radiation effects prediction capabilities for modern devices
    - Continue developing framework for user interface and models; make tool architecture realizable
    - Develop physics-based models of radiation performance for SEE in advanced CMOS such as Texas Instruments SRAMs and Xilinx FPGAs, leveraging other NEPP tasks where appropriate
    - Support use of framework for aiding Rad Hard foundry product development
    - Continue evaluating different physics-based codes (GEANT4, FLUKA, etc.) and developing appropriate particle models of interest for electronics technology

DELIVERABLES

Physics Based Modeling - Radiation

FY07 Deliverables	Quarter Due	Quarter Completed	Notes (changes to deliverable list or why not on schedule)
Continue development of framework for user interface and models.	4		
Develop physics based models for SEE performance of advanced CMOS products	4		
Develop preliminary technology model for advanced CMOS.	4		

SCHEDULE

Physics Based Modeling - Radiation

	2006			2007								
FY07	O	N	D	J	F	M	A	M	J	J	A	S
Framework Development												
Physics Based Models												
SEE Advanced CMOS												
First Order Tool												
SEE Advanced CMOS												

Lead Center/PI: Vanderbilt/Robert Reed
Co-Is: Vanderbilt/Robert Weller, et al,
GSFC/ Jean-Marie Lauenstein, Mike Xapsos
Funding summary:

NASA/NEPP	$???K
DTRA Procurement	$???K
Total	$???K

MAJOR ACCOMPLISHMENTS THIS QUARTER

Physics Based Modeling - Radiation

- SEU and MBU Model Development in Scaled CMOS
  - Texas Instruments (TI) 90 nm CMOS SRAM Process
    - Built TCAD model of sensitive volume and metalization for MRED analysis of neutron data provided by TI
    - Model of 42 SRAM cells in reasonable agreement with experimental measurement of SEU and MBU
  - Developed SEU Model of Sandia's 0.5 μm bulk CMOS6r 16 Kbit SRAM
    - Calibrated model with normal incidence low energy test data from BNL and minimal fabrication information
    - Successfully predicts angular dependence of direct ionization SEU for low and high energies

MAJOR ACCOMPLISHMENTS THIS QUARTER

Physics Based Modeling - Radiation

- Began development of experimental set-up for SEE testing of TI 65 nm CMOS SRAMs
- Began development of direct proton ionization simulations in highly scaled CMOS devices.
- SEL Modeling of TI 65 nm CMOS Technology
  - Found SEL dependence is a three dimensional problem with regard to the incident particle angle of incidence
  - Found SEL sensitivity depends on strike distance from n-well contact
  - Developed capability to model the full SRAM using TCAD

MAJOR ACCOMPLISHMENTS THIS QUARTER

Physics Based Modeling - Radiation

- SEU rate calculation for SiGe 3-D shift register stage
  - Evaluated Galactic Cosmic Ray (GCR) and Low Earth Orbit (LEO) upset rates for baseline and rad-hardened register
  - Based on charge collection efficiency model of IBM 5HP SiGe HBTs and model of cell layout
- Work was initiated to develop an RC network-based analytical model for SEGR in power MOSFETs
  - Background information on operation of power MOSFETs, heavy ion strikes in SiO_2/Si structures, and circuit simulators such as SPICE was reviewed.

MAJOR ACCOMPLISHMENTS THIS QUARTER

Physics Based Modeling - Radiation

- Publications and Presentations
  - R. A. Reed, *et al.*, “Impact of ion energy and species on single event effects analysis,” *IEEE Trans. Nucl. Sci.*, accepted, 2007.
  - P. E. Dodd, et. al “Impact of Heavy Ion Energy and Nuclear Interactions on Single-Event”, IEEE Trans Nucl. Sci., to be published in December 2007.
  - K. M. Warren, *et al.*, “Modeling alpha and neutron induced soft errors in static random access memories,” in *Proc. Int. Conf. IC Design & Technology*, Austin, TX: IEEE, May 2007.
  - K. M. Warren, *et al.*, “Predicting thermal neutron-induced soft errors in static memories using TCAD and physics-based Monte-Carlo simulation tools,” *IEEE Electron Device Lett.*, vol. 28, pp. 180-182, Feb. 2007.
  - K. M. Warren, *et al.*, “ Monte-Carlo Based On-Orbit Single Event Upset Rate Prediction for a Radiation Hardened by Design Latch” IEEE Trans Nucl. Sci., to be published in December 2007.
  - C. L. Howe, et. al “Distribution of Proton-Induced Transients in Silicon Focal Plane Arrays,” IEEE Trans Nucl. Sci., to be published in December 2007.
  - J. A. Pellish, et al., “A generalized SiGe HBT single-event effects model for on-orbit event rate calculations,” IEEE Trans. Nucl. Sci., accepted, 2007.
  - J. M. Hutson, *et al.*, “The effects of angle of incidence and temperature on latchup in a 65 nm technology,” *IEEE Trans. Nucl. Sci.*, accepted, 2007.
  - M. J. Gadlage, *et al.*, “Assessing alpha particle-induced single-event transient vulnerability in a 90 nm CMOS technology,” *IEEE Electron Device Lett.*, submitted.

TECHNICAL HIGHLIGHTS

Physics Based Modeling - Radiation

- MRED Development and Validation
    - Development of predictive SEU models based on limited test data and cost
        - TI and Xilinx 90 nm CMOS processes
        - Sandia 0.5 μm CMOS SRAM
        - Shift register stage composed of IBM SiGe HBTs
    - New MRED Simulation Flow
        - Incorporates MRED's radiation transport capability with a SPICE circuit simulator
            - "Critical Charge" parameter no longer needed for single event cross section and rate calculations

PLANS FOR NEXT QUARTER

Physics Based Modeling - Radiation

- Development of model for 65 nm TI CMOS technology
  - Create process and design model for MRED
  - Examine impact of angular dependence on error rate
  - Support testing on TI SRAMs
- Continue test board development for SEU, MBU and SEL experiments on TI 65 nm CMOS SRAMs.
- Develop a plan to address the impact of direct ionization from protons on modern technology.
- SEL modeling for 65 nm TI CMOS technology
  - Use TCAD model to map potential drops in the N-well and flag possible latching events
- Continue transient testing of SiGe HBTs with laser in order to understand event durations
- Continue development of analytical SEGR model.
- Begin work to define a metric for estimating the contribution of nuclear reactions to on-orbit SER from ground based test data

Partnering

Physics Based Modeling - Radiation

- DTRA procurement funding - $100 K
- Work partners
  - Funded organizations: Vanderbilt University
  - Other organizations: University of Florida, EMPC, SLAC, Geant4 Space User's Group, LANL, CERN, ESA, CNES, QinetiQ
- Leverage with other NEPP tasks
  - Scaled CMOS – Radiation
  - SiGe
  - Coordinate with NASA Radiation Hardened Electronics for Space Exploration (RHESE) Program

PROBLEMS AND CONCERNS

Physics Based Modeling - Radiation

- Test boards for SEE testing of the TI 65 nm CMOS SRAMs need to be re-spun. Proton testing will be delayed. There is also a possible delay in the heavy ion testing.